Evaluating Geometrical Parameters of Disperse Structures by the Images

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Abstract

Dispersion is an essential part of many technologies, so automated evaluation of generated drops diameters and their distributions is one of the major problems at the stage of technological processes study and adjustment.

The purpose of investigation is to develop a method of segmentation objects in the image, allowing improvement on particles recognition and efficient procession of their images in the presence of such contour defects as thin rays, fractal type shapes, presence a lot of objects in complex cases of their location in the image.

The paper marks out the methods improving image quality, the use of which gives the best results for dispersed formations images considering their specificity. A modification of image anisotropic filtering method and algorithm to improve emulsions image quality have been designed, which can significantly improve the quality of high frequency noise eliminating and separating the drops from background elements. There is improved path tracing procedure for images containing a large number of objects in complex cases of their location. Method can work well with open curves. Efficient method for plane figures "fast" measurement has been proposed. Method is based on numerical integration formulas, taking into consideration the errors made by the computer as a measuring device.

Statistical processing of drops size is made. The correspondence of empirical distribution to lognormal law is established. The software implementing the results of the investigation and combining all the stages of problem solving has been created.

The results can be used to study liquids dispersing problems, making and using various dispersed formations, including new materials and equipment development.

Keywords

Dispersive Formation; Image Filtration; Particles Measuring; Path Tracing; Thresholding; Statistical Processing

Introduction

In the solution of many practical problems in different industry areas there is a problem of evaluating objects parameters that cannot be measured directly.

Similar problems exist in determining the spray fineness and the effectiveness of different technical devices used for powders and emulsions making, and in determining the properties of some materials. Currently, the most actual thing is the developing methods for individual study of objects by their video images (Gonzales R.C. et al, 2005).

Some methods are based on direct measurement of required parameters, and other ones provide object modeling (Aulchenko S. M. et al, 2000 and Gribov M.G. et al, 2001). The papers by Rublev B.V., 1996 and Xiang Zhang et al, 2011 deal with direct measurement of such geometric parameters as the object curvature and perimeter. It should be noted that the dependence of the measurement results from the images quality, so the problem of image processing is carefully considered. A number of methods improving various images properties and making their computer analysis more efficient are described by Anisimov B.V. et al., 1983; Bronnikov A.V. et al., 1990; Bryan S. Morse, 1998-2000; Loo P.K. et al, 2003; T. Pavlidis, 2012; Pratt W.K., 2007;.Singh V. et al, 2004.

The Purpose of Investigation

Discussed ways solving image processing problem focus on a specific problem and specific geometry of processed objects. This fact needs further research aimed at increasing the efficiency of computer video measuring methods. Therefore, our task is to develop a method to identify objects in the image, allowing improving recognition and efficiently processes figures images in the presence of such contour defects as thin rays, fractal type shapes, presence a lot of objects in complex cases of their location in the image. There is created efficient method plane figures "fast" measurement. Method evaluates the errors made by the computer as a measuring device (Yeliseyev V.I. et al, 1999). Method can be the basis for measuring

systems, working with large series of images in real-time mode

Methods

Image of the emulsion to be processed presented in Fig. 1. Images obtained from a video camera are often dull, with obscured objects, "dirty" background areas. Histogram analysis of images shows that they have evident disbalans according to low brightness values and do not cover the tonal range. This fault is typical for most of emulsion images. To solve this problem, method of lights and shades redefining can be used. It transforms the histogram so that it covers the whole tone interval (T. Pavlidis, 2012 and Pratt W.K., 2007).

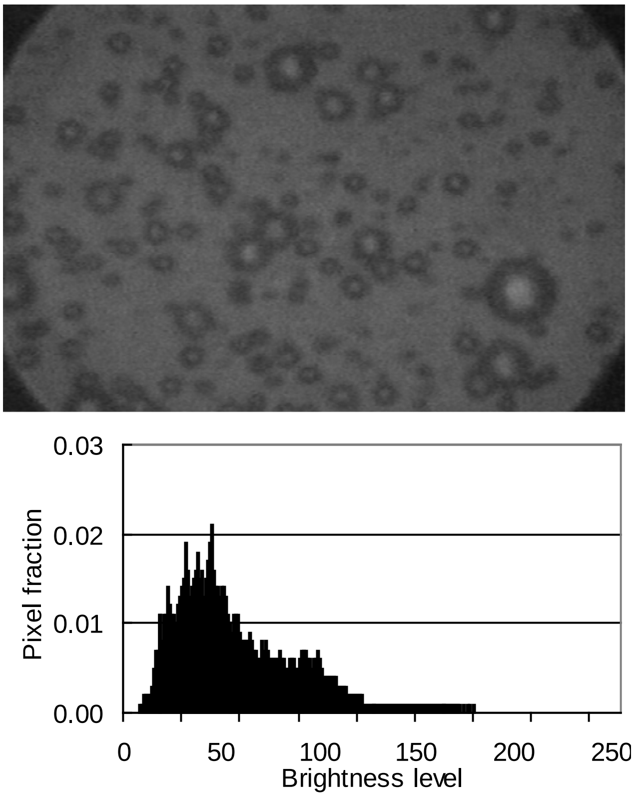


FIG. 1 EMULSION DROPS IMAGE OBTAINED FROM A CAMERA AND ITS HISTOGRAM

Method includes overriding the brightness value of the lightest and the darkest pixel in the image and the linear mapping of the existing tone interval [g_{min}, g_{max}] to the new one $[\tilde{g}_{min}, \tilde{g}_{max}]$ according to formula

$$\tilde{g} = \frac{(\tilde{g}_{max} - \tilde{g}_{min})(g_{min} - g)}{(g_{min} - g_{max})} + \tilde{g}_{min}, \quad g_{min} \le g \le g_{max}$$

where g – brightness level value in old tone interval; $\tilde{g}$ – corresponding value in new one.

Application of this method to the image shown in Fig. 1, is presented in Fig. 2.

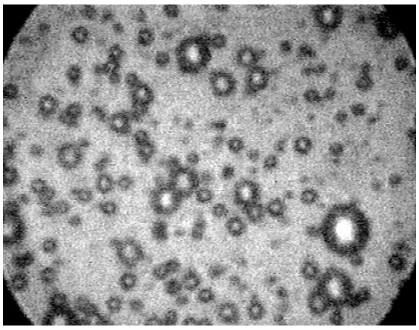


FIG. 2 EMULSION IMAGES CORRECTION BY LIGHTS AND SHADES REDEFINING METHOD

This procedure can be recommended as the initial stage of emulsions image processing.

To smooth the background elements and "cleaning" the picture and to decrease the high frequency noise that appears as a result of histogram stretching, moving average filter can be used. Good results can be also obtained by combined filter (Bronnikov A.V. et al, 1990). Directional filter (T. Pavlidis, 2012) may be considered as an alternative to the moving average filter. But this method is not always suitable, as it can cause shades amplification.

Image recognition and geometrical parameters calculation requires unambiguous separating the object from the background. Some noisiness and the presence of shades greatly complicate the problem. Otsu method has been implemented to transform image to monochrome mode. The results are shown in Fig. 3.

Otsu method (Bryan S. Morse, 1998-2000) considered the image consisting of two pixel groups having different ranges of values, which can overlap. The problem is to take the limit value minimizing shared space and divide the pixel group with maximum efficiency. Optimum limit value must maximize intergroup variance.

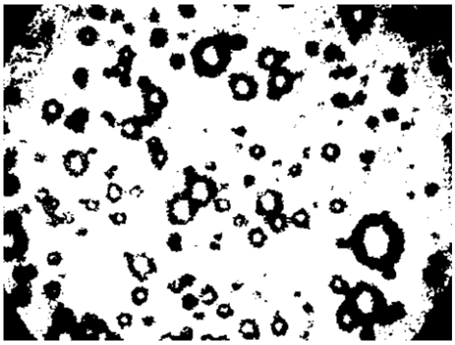


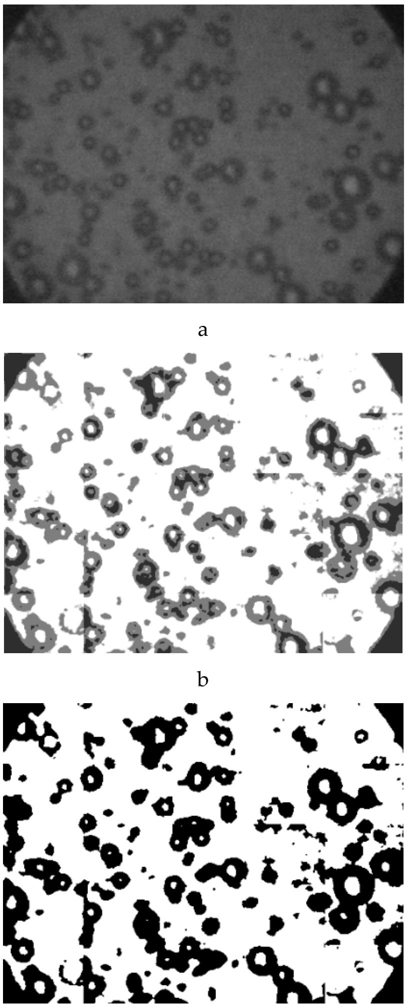
FIG. 3 TRESHOLDING IMAGE BY OTSU METHOD

Modified two-pass image anisotropic filtering method designed by the authors can be recommended. It is realized by the formula

$$\tilde{g}(x,y)=\left[\sum_{i,j=-M}^{M} H(i,j)g(x+i,y+j)-\eta\right]\cdot \Lambda$$

where M is a smoothing window size; H – smoothing filter function; $\Lambda(x)$ – threshold function, $\Lambda(x)=0$ at $x<0$ and $\Lambda(x)=1$ at $x>0$.

In the difference to the anisotropic filtering method described by Anisimov B.V. et al, 1983, first it reduces image to 256-tones then to 4-tones, and then - to 2 colors - black and white by the system of experimentally selected weights and thresholds. In most cases, its application to emulsion images gives a satisfactory result (Fig. 4).



a

b

c

FIG. 4 – REDUCING EMULSION IMAGE TO BIT-MODE BY MODIFIED ANISOTROPIC FILTERING METHOD:

a – initial image; b – 4-tones image; c – 2-tones image

To increase the efficiency of filtering image processing is realized in parts. The advantages of this method are the combining of segmentation and filtering processes and the possibility to achieve the optimal results by fine tuning and specific parameters considering. The result of the Otsu method can be improved by preliminary usage of low-pass filter to smooth background irregularity.

There are also a number of machine parts images with alphanumeric labeling or bar-codes printed on them. The feature of these images is almost total lack of information about the analyzed object, and therefore the methods based on a priori limit values setting and weights are not suitable.

Problem of effective marker segmentation is set concerning to above mentioned images and the segmentation quality of the rest of the image may be neglected. In this case, the authors propose to set limit value not by the mean value of entire image, but by the part of it that is of interest to us (contains the analyzed object). We propose to consider a large average gradient of brightness to be sign of this area.

Thus, all mentioned above, allows us to propose procedure to improve the emulsions image quality: stretching tone interval of image using method of lights and shades redefining, low-frequency noise smoothing (moving average filter, directional or combined filter, anisotropic filtering method), the separating the pixel by brightness (Otsu method, two-pass method of anisotropic filtering).

Object contour identification, according to the basic method of contour forming (Anisimov B.V. et al, 1983.) is made in the next step. Method is improved in order to make it possible to process many objects in a single image, especially in complex cases of their location by two colors system that are unique for each object, and defined as follows:

$B = N \; mod \; Base$; $a_g=N \; div \; Base$;

$G = a_g \; mod \; Base$; $a_r=a_g \; div \; Base$;

$R = a_r \; mod \; Base$,

where $x \; mod \; y$ – remainder extraction at integer division number x by number y; $x \; div \; y$ – evaluating the ratio x by y.

So, the color, components of which are calculated according to the above algorithm, can be a criterion of belonging pixel to the object. To synthesize object's color we will change color's component from 0 to 127 (the parameter Base is set equal to 128), and to synthesize the outline color it is sufficient to add 128 to the corresponding component of the object color. This separation is useful at fractal structures processing and visual analysis of their external contour.

In the case presented Fig. 5a the path tracing procedure is quite simple. Every time we add to

coordinates list a new boundary point along the path tracing direction. There is quite different situation when making a coordinates list for contour in Fig. 5b.

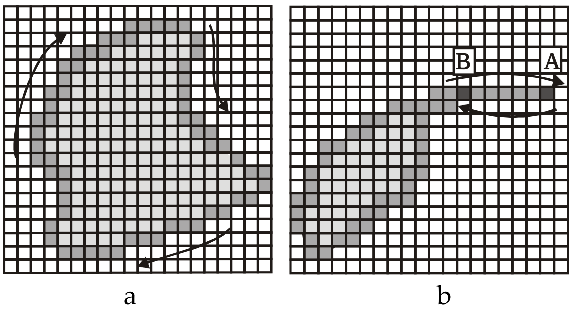


FIG. 5 PATH-TRACING FEATURES OF OBJECTS OF DIFFERENT CONFIGURATION

Feature is one pixel width sections, which may be caused by the presence of thin protrusions on real object or effect of contour unclosedness. Frequently, presence of the ridges is caused by the image noises and segmentation because of non-uniform lighting at the object surface. In this case we trace one pixel with section twice as section AB (Fig. 5b). First trace in the direction from B to A and then from A to B. So, points of BA segment we include in coordinates list two times according to contour trace procedure. After that we start to search the next black point at workspace - the initial point of the next object. Because of the fact that previously processed objects are filled with other colors, points generating them do not distort search pattern, regardless of the objects form and arrangement

On determining coordinates of contour points, we can start measuring. Thus, the area is evaluated by numerical integration while element tracing by formula $S=\sum_{i=1}^{n} y_i \Delta x_i$ where y_i is height coordinate of the current point, Δx_i is the distance between the centers of adjacent pixels. On the basis on the finite-difference representation of the curve element $\Delta P_i=\sqrt{(\Delta x_i)^2+(\Delta y_i)^2}$ it can be written expression for perimeter $P=\sum_{i=1}^{n} \Delta P_i$, but calculating parameters for some simple figures by this formula shows a big error. Authors propose to represent figure perimeter as $P=\sum_{i=1}^{n} \beta_i \Delta P_i$ for more accurate evaluation, where β some smoothing factor, found experimentally. There is considered line segment of known length and turned around its center. Smoothing factor β is evaluated for each rotation angle Θ and tabulated. The curve β(Θ) (0° ≤ Θ ≤ 45°) is built on the base of tabular data. Then curve is approximated. Analytical coefficients representation is obtained by approximating:

$$\beta(\Theta)=-0.0022+0.0182\,\Theta-0.0002\,\Theta^2 .$$

Arbitrary permeter can be represented as

$$P=\sum_{i=1}^{n} \beta'(\Theta_i)\Delta P_i ,$$

где P_i– perimeter of curve element; Θ_i – inclination angle of this element to grid lines. $\beta'(\Theta)$ smoothing function based on factor $\beta(\Theta)$.

The expression may be the basis of "fast" algorithm for perimeter evaluation.

There is made statistical processing of drops size to obtain the statistical characteristics of the emulsion. A number of emulsion video images has been processed by computer. Contours of represented drops are identified and diameters are evaluated. Recognition results of these photos are merged into one sample. First, the primary statistical analysis of the sample is made. The sample is splitted into intervals, frequency, the middle value, relative frequency, cumulative relative frequency (value of empirical distribution function), and the value of empirical probability function are evaluated. To visualize the results are presented as a charts of empirical distribution function (Fig. 6) and empirical probability density function (Fig. 7)

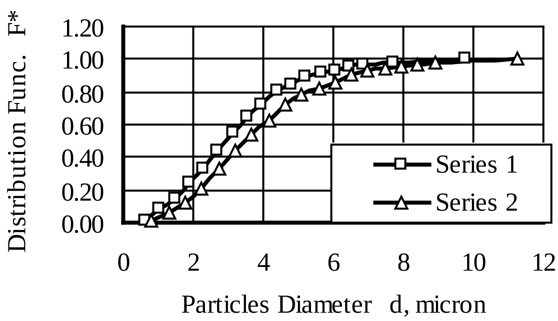


FIG. 6 EMPIRICAL DISTRIBUTION FUNCTION

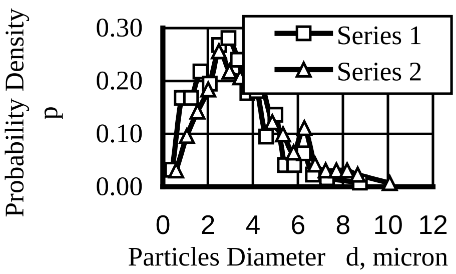


FIG. 7 EMPIRICAL PROBABILITY DENSITY FUNCTION

The curves obtained from procession of the two experimental series are presented in Fig. 6 and Fig. 7. Series consist of 532 drops (series 1) and 556 drops (series 2), a series are differ in water content (series 1 – 7%, series 2 – 10%).

Using the standard formula, we calculate the main parameters for both of two studied experimental series. Values presented in Table 1 are the final values obtained as a result of video images filtering, eliminating "accidental" drops, which could be the result of retouching, contrasting and other operations to improve image sharpness.

Authors are used algorithm of the least dependency on the distribution kind for outliers elimination. The procedure of splitting the sample into classes (with further statistical analysis) and outliers removing is iterative and performed to until homogeneous sample is obtained.

TABLE 1 KEY PARAMETERS OF EXPERIMENTAL SERIES

Series	Mean Value $\bar{x}$	Variance s^2	Mean Square Deviation s	Asymmetry k_{as}	Excess k_{exc}
Series 1	3.15	2.80	1.67	0.90	3.96
Series 2	3.82	3.81	1.95	1.89	3.67

It is known that the distribution of dust, powders, aerosols and other dispersed formations often follow lognormal law (Kouzov P.A., 1987.), its distribution function is

$$F_x(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{(\ln(x+\Theta)-\xi)/\sigma} e^{-u^2/2} du \ , \qquad (1)$$

if $\ln(x+\Theta)$ is normally distributed $N(\xi,\sigma)$.

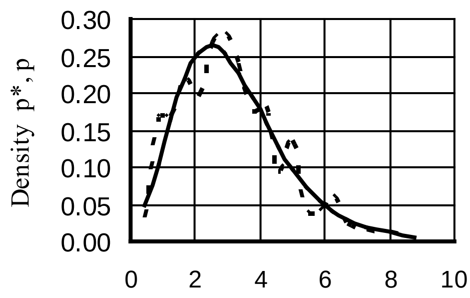
Θ is fitted to provide the best correspondence between empirical and theoretical distributions to minimize the deviation measure (χ^2 criterion).

Empirical probability density function and the density function of fitted lognormal distribution are in Fig. 8. Fig. 8 presents that the empirical distributions are slightly differ from fitted theoretical curves. Estimation of deviation measure made according to χ^2 criterion shows that verificated hypothesis of diameters lognormal distribution may be considered valid with 98% probability.

Lognormal distribution parameters θ, ξ, σ (1) are calculated, the values are in Table 2.

TABLE 2 PARAMETERS OF FITTED LOGNORMAL DISTRIBUTION

Series	θ	ξ	σ
Series 1	2.43	1.68	0.29
Series 2	1.30	1.57	0.38



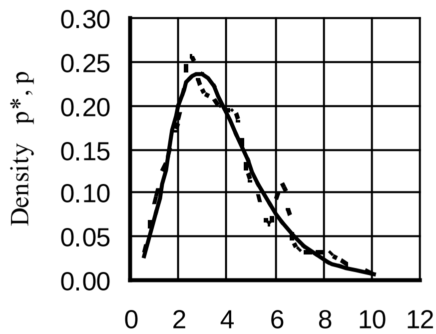


FIG. 8 EMPIRICAL PROBABILITY DENSITY FUNCTION *(P*)*, DENSITY FUNCTION OF FITTED LOGNORMAL DISTRIBUTION *(P)*

*p** – dashed line; *p* – continuous line

From the analysis of the statistical characteristics of found distributions it follows that drops diameters values obtained at dispersion qualitatively follow the same theoretical law, but with its different parameters, so the change in water content in emulsified fuel within studied interval does not lead to qualitative changes in the distribution, but changes its characteristics. This makes it possible to compare the features of different dispersion methods within certain statistical laws.

Conclusions

The paper marks out the methods improving image quality, the use of which gives the best results for dispersed formations images considering their specificity. A modification of image anisotropic filtering method and algorithm for improving emulsions image quality are designed. There is

improved path tracing procedure for images containing a large number of objects in complex cases of their location. Method can work well with open curves. There is created efficient method for "fast" measurement of plane figures. Method is based on numerical integration formulas, taking into consideration the errors made by the computer as a measuring device. Statistical processing of drops size is made. The correspondence of empirical distribution to lognormal law is established.

The software implementing the results of investigation and combining all the stages of problem solving was created.

The results can be used to study liquids dispersing problems, making and using various dispersed formations, including the new materials and equipment development.

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